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Growth and yield of rice-wheat in response to integrated use of organic and inorganic N sources

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Abstract

This study was conducted to evaluate the effect of integrated use of organic and inorganic nitrogen (N) sources on rice-wheat yield and yield parameters, soil organic carbon content and nitrate leaching. Fourteen treatments viz: control (No NPK), 100% N through fertilizer (Recommended NPK), 100% N through FM, 100% N through press mud, 100% N through poultry litter, 75% N through fertilizer + 25% N through FM, 75% N through fertilizer + 25% N through press mud, 75% N through fertilizer + 25% N through poultry litter, 50% N through fertilizer + 50% N through FM, 50% N through fertilizer + 50% N through press mud, 50% N through fertilizer + 50% N through poultry litter, 25% N through fertilizer + 75% N through FM, 25% N through fertilizer + 75% N through press mud, 25% N through fertilizer + 75% N through poultry litter were tested. All organic manures were well mixed in soil before filling the pots. The results indicated that maximum plant height, number of tillers, number of grains per spike/panicle, 1000 grains weight and paddy/grain yield was obtained in treatment where 75% N through chemical fertilizers and 25% N through poultry litter was applied. The highest soil organic carbon after the harvest of rice and wheat was obtained in treatment where 100% N was applied through farm manure while soil nitrate was maximum in treatment where 75% N through chemical fertilizers and 25% N through poultry litter was applied. The study conjectured that combination of chemical fertilizers and poultry litter (75:25) proved best in comparison with other integrations and sole applications.

Keywords: Rice, wheat, pressmud, farm manure, poultry litter

Introduction

Pakistan is situated in arid and semiarid conditions where rain fall is low and unevenly distributed. Cereals are an important dietary protein source throughout the world, because they constitute the main protein and energy supply in most countries (Bos *et al.*, 2005). Wheat and rice are two major grain crops grown in Pakistan. Wheat is one of the major cereal crops with a unique protein, which is consumed by humans and is grown around the world in diverse environments. Rice (*Oryza sativa* L.) has supported a greater number of people for a longer period of time than any other crop since it was domesticated between 8,000 to 10,000 years ago (Fairhurst and Dobermann, 2002). Because of its political, economic, and social significance, rice remains the most important crop grown in the world (Greenland, 1997). Chemical fertilizers play a significant role in boosting crop production on alkaline calcareous soils of Pakistan (Ahmad, 2000). Despite increased use of the fertilizers, per hectare yield has not been increased proportionally rather stagnation has occured (Ali, 2000). This has been attributed to the imbalanced use of mineral fertilizers and inappropriate method of their application that has culminated in low efficiency.

Continuous use of chemical fertilizers even in balanced proportion will not be able to sustain crop productivity due to deterioration in soil health (Zia *et al.*, 2000). The problem of decreasing land fertility, use of high doses of inorganic fertilizers and the ever increasing cost of inorganic fertilizers are factors considered harmful for sustainability of production systems (Adhikari, 2011). Nutrient recycling by the use of organic manures is preferred to restore nutrient removed by crops (Jobe, 2003). But application of only organic manures inefficiently improves the yield per unit area (Jobe, 2003; Satyanarayana *et al.*, 2002). Therefore, integrated management of plant nutrients can diminish this problem and it could be suitable for any farming system and socio-economic conditions (Lamps, 2000). A combination of mineral fertilizers and farmyard manure has been suggested as the most effective method to maintain a healthy and sustainable soil system while increasing crop productivity (Satyanarayana, 2002; Balesh, 2006; Zelalem *et al.*, 2009). Keeping above facts in

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view, the present study was conducted to evaluate the effect of integrated use of organic and inorganic fertilizers on rice-wheat growth, yield, soil organic carbon and nitrate contents.

Materials and Methods

The pot experiments were conducted at the wire house of Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad, Pakistan (Latitude, 31°.40' N and Longitude 73°.05' E, 189 m ASL). The soil used was well-drained Hafizabad sandy clay loam, mixed, semi-active, isohyperthermic Typic Calciargids (Table 1). The pots were filled with air dried soil at 10 kg pot^{-1}. The corresponding amounts of mineral fertilizer, farm manure, poultry litter and press mud were thoroughly mixed with the soil before filling the pots according to the treatments viz: T_1: Control (No NPK), T_2: 100% N through fertilizer (Recommended NPK), T_3: 100% N through FM, T_4: 100% N through press mud, T_5: 100% N through poultry litter, T_6: 75% N through fertilizer + 25% N through FM, T_7: 75% N through fertilizer + 25% N through press mud, T_8: 75% N through fertilizer + 25% N through poultry litter, T9: 50% N through fertilizer + 50% N through FM, T_{10}: 50% N through fertilizer + 50% N through press mud, T_{11}: 50% N through fertilizer + 50% N through poultry litter, T_{12}: 25% N through fertilizer + 75% N through FM, T_{13}: 25% N through fertilizer + 75% N through press mud, T_{14}: 25% N through fertilizer + 75% N through poultry litter.

The rice variety Super Basmati nursery was grown in a well manured soil with recommended management practices for rice nursery. Twenty five days old rice seedlings (6 plants per pot) were transplanted into pots arranged randomly under ambient temperature and light. The pots were arranged according to completely randomized design with three replicates.

After seedling transplantation, the pots were flooded with canal irrigation water. The recommended rice production and protection measures were followed throughout the crop growth period up to maturity. After rice harvest, same pots were used for wheat crop (cv. Faisalabad-2008). At maturity of each crop, the data regarding growth and yield parameters (number of tillers per pot, plant height, number of grains per panicle/spike, biomass, paddy yield, wheat grain yield and 1000-grain weight) were recorded. The soil samples were taken from each pot for determination of soil organic carbon and nitrate contents. Soil organic carbon was determined following the method described by Ryan *et al*. (2001) while nitrate-N was determined by chromotropic acid method (Hadjidemetriou, 1982). The organic sources (farm manure, press mud, poultry letter) were characterized for NPK and organic carbon contents (Table 2) following standard methods (Bremner and Mulvaney, 1982; Kuo, 1996; Nelson and Sommers, 1996). Statistical analysis was performed using Statistic 8.1 (http://statistix.software.informer.com/). Least significant differences (LSDs) were used for comparing treatment means (Steel *et al*., 1997).

Table 1: Physical and chemical characteristics of the soil

Characteristic	Unit	Value
Sand	%	65.3
Silt	"	20.9
Clay	"	13.8
Textural Class	Sandy clay loam	
EC_e	dS m^{-1}	1.60
pH		7.9
Soil organic carbon	g kg^{-1}	2.0
Total nitrogen	g kg^{-1}	0.45
Available phosphorus	mg kg^{-1}	7.0
Available potassium	mg kg^{-1}	122.5
NO_3^-	mg kg^{-1}	5.42

Results and Discussion

Growth attributes

The results regarding effect of integration of organic and inorganic fertilizers on agronomical parameters of rice and wheat are given in Table 3 and 4. The direct/ residual integrated application of organic and inorganic sources of nitrogen had significant effect on plant height of rice and wheat. The maximum plant height (119.4 cm) of rice was observed in T8 while minimum (101.5 cm) was observed in control (no NPK) (Table 3). Similar trend was observed in case of wheat crop (Table 4).

The increase in plant height in response to combined application of organic and inorganic manures might be due to enhanced availability of macro nutrients and micro nutrients. Application of mineral N alone or with organic N increased plant height significantly due to the stronger role of N in cell division; cell expansion and enlargement which ultimately affect the vegetative growth of wheat plant particularly plant height (Iqbal *et al*., 2002; Idris *et al*., 2001; Idris and Wisal, 2001; Singh and Agarwal, 2001). The results of present study are supported by the findings of Usman *et al.* (2003).

Grain yield and contributing attributes

The data presented in Table 3 and 4 showed that the number of grains per panicle/spike of rice and wheat was significantly affected by integrated application of organic and inorganic sources of nitrogen. The maximum number

of grains per panicle/spike (96 and 39, respectively) was obtained in treatment T8 and the same treatment depicted maximum 1000 grain weight of rice (17.7 g) and wheat (29.3 g). The maximum paddy/grain yield and harvest index (234 and 89.3 g, 20.9 and 35.0%, respectively) was found in T8 treatment also. The maximum percent increase over control in rice and wheat was (95 and 111%, respectively) obtained in treatment (T8) where integration of chemical fertilizers and poultry manure (75:25) was used. This is due to better utilization of phosphorus in the presence of organic manures. These results are also in accordance to that of Bajpai *et al.* 2002; Pooran *et al.*, 2002; Usman *et al.*, 2003; Yaduvanshi, 2003; Alam *et al.*, 2005 and Shah *et al.*, 2010.

Post harvest soil chemical attributes

The maximum soil organic carbon (SOC) concentration (Table 5) in soil after rice and wheat harvest (2.86 and 3.47 g kg^{-1}, respectively) was observed in treatment T3. Whereas the highest nitrate concentration in soil was observed in treatment T8 and minimum in T1 after the harvest of both crops. Post harvest analysis depicted higher carbon and nitrate contents in farm manure and poultry litter respectively. As farm manure had higher contents of carbon and less contents of nitrogen in composition and poultry litter had vice versa contents of carbon and nitrogen. The results are very much promising with the organic sources composition. Sole application of organic sources showed relatively higher carbon contents compared with integration because of chemical fertilizers addition that mineralized them.

Table 2: Analysis of different manures used

Parameter	Unit	FYM	Pressmud	Poultry litter
Moisture contents	(%)	50 ± 2.50*	50 ± 3.30	7 ± 1.21
N	-	0.98 ± 0.02	2.0 ± 0.03	2.5 ± 0.02
P_2O_5	-	0.47 ± 0.02	1.09 ± 0.01	1.0± 0.015
K_2O	-	1.58 ± 0.04	0.88 ± 0.03	0.90 ± 0.025
Organic carbon	-	48.1 ± 1.60	31.5 ± 1.23	20.8 ± 1.12

* Average ± Standard error with three repeats

Table 3: Effect of integrated use of organic sources of nitrogen and chemical nitrogen on yield and yield contributing parameters of rice under pot condition

Treatment	Plant height (cm)	No. of grains/ panicle	1000 grain weight (g)	Paddy yield (g/pot)	Harvest Index (%)	% increase over control
T_1	101.5 f	79.0 e	11.0 d	120 c	16.4 f	-
T_2	116.4 ab	96.0 a	16.0 ab	216 a	20.8 ab	80
T_3	103.5 f	86.0 be	11.7 cd	174 ac	18.8 ae	45
T_4	106.1 ef	84.0 ce	11.3 d	126 bc	19.9 ac	5
T_5	106.9 df	88.0 ad	14.7 ac	160 ac	19.7 ad	33
T_6	116.3 ab	86.0 be	16.7 ab	210 ab	17.5 df	75
T_7	115.7 ab	92.0 ab	16.0 ab	199 ac	20.1 ac	66
T_8	119.4 a	96.0 a	17.7 a	234 a	20.9 a	95
T_9	115.3 ab	90.0 ac	15.0 ab	198 ac	18.6 bf	65
T_{10}	113.9 ac	92.0 ab	15.0 ab	170 ac	20.0 ac	42
T_{11}	115.4 ab	93.0 ab	16.7 ab	174 ac	18.49cf	45
T_{12}	111.0 be	81.0 de	14.3 bd	166 ac	19.9 ac	38
T_{13}	107.6 cf	84.0 ce	16.3 ab	178 ac	17.3 ef	48
T_{14}	113.7 ad	89.0 ad	14.3 bd	160 ac	17.9 cf	33

Yields were generally highest for the 100% N treatment and reduced when 100 % organic sources were used indicating that the organic N was not fully available as the application was based on total N of the organic source, not the plant-available N while the mineralization of the organic N was delayed (out of sync with crop uptake) to a point where yield losses were incurred. Organic manures increased the fertilizer use efficiency and improved the physical and chemical properties of soil hence making better utilization of nutrients, might also be a reason towards increased yield.

Table 4: Residual effect of organic sources of nitrogen and chemical nitrogen on yield and yield contributing parameters of wheat

Treatment	Plant height (cm)	No. of grain/ Spike	1000 grain weight (g)	Grain yield (g/pot)	Harvest Index (%)	% increase over control
T_1	62.4 c	26ns	22.3ns	42.3c	27.0 d	-
T_2	67.6 a	36	24.3	81.7ab	32.1 ac	93
T_3	63.8 bc	23	23.7	63.7b	34.5 ab	49
T_4	64.9 ac	21	24.3	64.0b	32.8 ac	51
T_5	65.3 ac	24	25	66.7b	31.6 ac	58
T_6	66.8 ab	38	23.3	79.0ab	31.7 ac	87
T_7	66.6 ab	36	23.3	76.7ab	31.3 ac	81
T_8	68.5 a	39	29.3	89.3a	35.0 a	111
T_9	66.3 ab	34	23.7	73.3ab	30.9 bc	73
T_{10}	66.0 ac	34	27.7	72.7ab	31.1 ac	72
T_{11}	66.5 ab	35	29.0	73.3ab	30.4 cd	73
T_{12}	65.5 ac	31	25.7	69.0ab	29.8 cd	63
T_{13}	65.5 ac	30	25.3	67.0b	31.6 ac	58
T_{14}	65.9 ac	32	26.7	71.7ab	30.8 bcd	70

Table 5: Effect of direct/residual organic sources of nitrogen in combination with inorganic nitrogen on soil organic carbon and Nitrate after rice and wheat harvest under pot conditions

Treatment	Rice		Wheat	
	SOC	NO_3^{-1}	SOC	NO_3^{-1}
	g kg^{-1}	mg kg^{-1}	g kg^{-1}	mg kg^{-1}
T_1	2.04 b	10.32 e	2.16 d	12.90 d
T_2	2.01 b	23.59 ab	2.60 cd	20.38 ac
T_3	2.86 a	15.50 ce	3.47 a	13.55 bd
T_4	2.72 a	14.26 de	3.21 ac	12.30 d
T_5	2.53 ab	18.20 bd	3.00 ac	14.73 bd
T_6	2.43 ab	24.95 ab	3.08 ac	20.74 ab
T_7	2.39 ab	22.42 ac	2.92 ac	18.59 ad
T_8	2.21 ab	28.34 a	2.78 bd	22.52 a
T_9	2.43 ab	20.44 bd	3.29 ab	14.82 bd
T_{10}	2.35 ab	18.21 bd	3.06 ac	15.94 ad
T_{11}	2.32 ab	21.95 ac	2.95 ac	17.24 ad
T_{12}	2.74 a	14.45 de	3.42 ab	13.86 bd
T_{13}	2.57 ab	13.92 de	3.07 ac	13.25 cd
T_{14}	2.47ab	16.17 ce	2.98ac	14.24 bd

Conclusion

Sole application of organic sources on the basis of nitrogen dose as per recommendation produced positive impact on soil properties but yield of rice/wheat remained lower compared with chemical fertilizers and integrated approach of organic and inorganic fertilizers because of delayed availability of plant nutrients. However integration of chemical fertilizer and poultry litter (75:25) was found best for obtaining maximum yield of rice/wheat.

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